

# Chapter 11

## Economics in the Management of Mountain Pine Beetle in Lodgepole Pine in British Columbia: A Synthesis

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### Abstract

Economic theory has played only a minor role in developing British Columbia's forest strategy for managing the mountain pine beetle (*Dendroctonus ponderosae* Hopk. [Coleoptera: Scolytidae]). Forest economics literature addresses the forest management problem caused by the beetle in lodgepole pine (*Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm.) from a number of perspectives. The standard methods are concerned with maximizing the value of harvesting a single forest site under the risk of bark beetle. The second viewpoint extends this value-maximizing approach to incorporate multiple uses of, and benefits from, a larger forest system. In this second approach, management policy suggests systems that reduce risk and reduce impact, rather than increase physical product. This chapter discusses literature from these two viewpoints and identifies issues, opportunities and concerns of applying forest economic theory to the mountain pine beetle problem in British Columbia.

### Résumé

La théorie économique n'a joué qu'un rôle mineur dans l'élaboration d'une stratégie de lutte contre le dendroctone du pin ponderosa (*Dendroctonus ponderosae* Hopk. [Coleoptera: Scolytidae]) en Colombie-Britannique. La littérature traitant d'économie forestière aborde, de divers points de vue, le problème que pose le dendroctone du pin ponderosa dans la gestion des forêts de pins tordus latifoliés (*Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm.). Un des points de vue indique que les méthodes classiques visent à maximiser la valeur de la récolte des arbres d'une forêt donnée exposés au risque que représente le dendroctone du pin ponderosa. Un second point de vue élargit cette approche de la maximisation de la valeur de façon à intégrer les multiples utilisations et avantages associés à un système forestier plus vaste. Dans cette seconde approche, la politique d'aménagement propose des méthodes visant à réduire le risque et l'impact que représente le dendroctone du pin ponderosa plutôt qu'à accroître les volumes exploitables. Le présent chapitre porte sur les divers ouvrages qui traitent de ces deux points de vue, et on y précise les questions, les possibilités et les difficultés reliées à l'application de la théorie économique forestière au problème que représente le dendroctone du pin ponderosa en Colombie-Britannique.

## Introduction

Forest resources and their associated products are extremely important to British Columbia's economy. Between 1992 to 2001, forest products exports from the province brought in an average of \$14.4 billion per year and accounted for 43% of the export base of the province (Baxter and Ramlo, 2002). This large amount of economic activity associated with commercial forest use suggests an economic perspective that may give meaningful insight to understanding most provincial forestry issues including the current epidemic of mountain pine beetle (*Dendroctonus ponderosae* Hopk. [Coleoptera: Scolytidae]).

The relationship between lodgepole pine (*Pinus contorta* Doug. ex Loud. var. *latifolia* Engel.) forests and the mountain pine beetle has been developing in western Canada since the retreat of the ice thousands of years ago (Cwynar and MacDonald 1987). Beetle population outbreaks have been recorded in some parts of British Columbia since 1910, and evidence of mountain pine beetle activity going back hundreds of years is found in strip scars on lodgepole pine trees (Mitchell et al. 1983) and tree-ring analyses (Heath and Alfaro 1990). On the other hand, extensive forest management of lodgepole pine has been ongoing for less than 60 years, hardly time for scientific understanding of the interrelationships in and between complex bio-economic systems.

Lodgepole pine is found in many forest types of interior British Columbia. Mulholland (1937) states:

At elevations from 3,500 to 5,500 feet increased precipitation produces denser stands, and the larch and fir give place to spruce and alpine fir, forming a type similar to the northern forest. Large areas of this type have been replaced by pure lodgepole pine as a result of fires, and this species is also found in varying proportions among the spruce and alpine fir. The majority of the immature stands throughout the whole Interior are pure lodgepole pine, often in dense thickets; for this reason lodgepole pine will be of importance in future management of Interior forests.

The stands to which Mulholland alluded are almost 70 years older now. Many of them are considered mature; some are being attacked by mountain pine beetle and others are already dead.

Lodgepole pine covers more than 14 million ha and, by volume makes up between 15% and 25% of the province's total standing timber inventory. Lodgepole pine volumes are proportionally higher in interior portions of the province and are critical to the timber supply of the interior British Columbia forest sector (British Columbia Ministry of Forests 1995). Province-wide, the contribution of lodgepole pine stands to the annual harvest has increased from approximately 14 million m<sup>3</sup> in 1980 to over 20 million m<sup>3</sup> in 2001 (Fig. 1). The species is thus very important from an economic point of view.

During the early years of the development of forestry in British Columbia, many stands of lodgepole pine were immature, a result of fires that burned throughout western North America before the turn of the century (Agee, 1993). In the last 75 years, one of the major

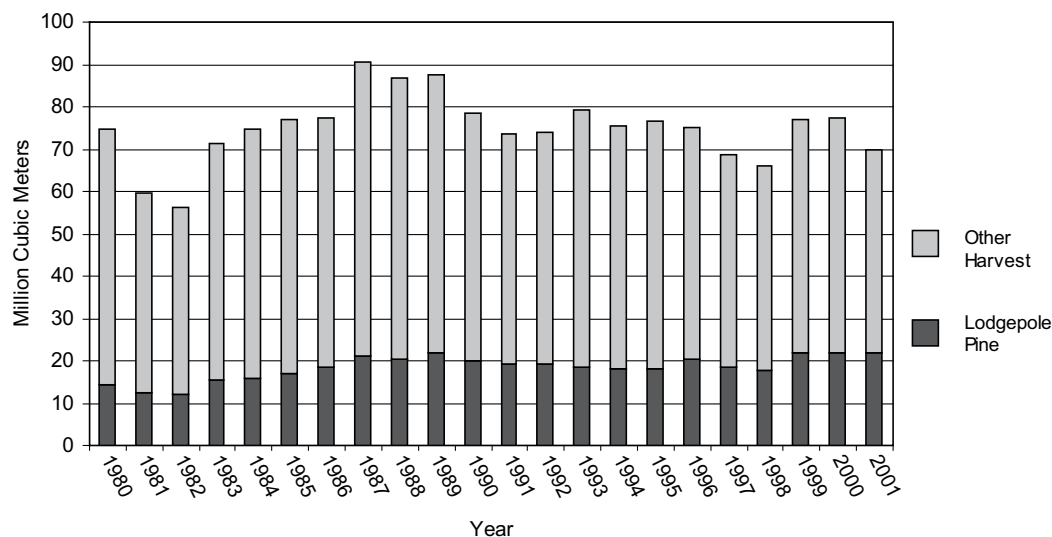


Figure 1. Lodgepole pine component of annual timber harvest in British Columbia (Source: British Columbia Ministry of Forests Annual Reports 1980-2001).

goals of forestry in the province has been to minimize wildfire damage. As a consequence, stand-replacing fires common in the 19<sup>th</sup> century were for the most part not duplicated in the 20<sup>th</sup> century. Because the development in the province's interior forests was delayed until after World War II, many juvenile stands of lodgepole pine matured, while older stands became over-mature.

Historically, lodgepole pine has also ranked low as a commercial species. As a result, the species was often by-passed in favour of more economically valuable species during the early stages of provincial forest sector development. Thus, it should not be surprising that a large fraction of the species now exists as mature and over-mature age classes. These older mature trees are most susceptible to beetle attack (Amman 1977; Amman and Safranyik 1985).

For the past 25 years, British Columbia's pine forests have suffered increasing losses in value from a variety of disturbance events. These include wildfires and wind, which are physical in nature, and insects and diseases, which are biological. As forests age, they become increasingly vulnerable to disturbance agents (Christiansen et al. 1987). Disturbance agents, such as wind, insects and fire, often work in combination, but their cumulative effect has been only rarely investigated quantitatively (Bebi et al. 2003; McCullough et al. 1998; Safranyik et al. 2001).

Figure 2 indicates the rate of mountain pine beetle population increase in the west-central interior of British Columbia during recent years. With 4 million ha of red attacked lodgepole pine in 2003<sup>1</sup> (British Columbia Ministry of Forests 2004), the current outbreak is the largest in British Columbia's short history of record keeping. Petersen (2003b) noted that

<sup>1</sup>The 2003 estimate is based on red attack resulting from beetle flight in 2002. Thus, the estimate understates the infestation produced by the 2003 beetle flight.

within the 4.2 million ha surveyed in 2003, the intensity level of attack varied. Intensity was rated as 64% light (1% to 10% of trees being dead), 18% moderate (11% to 29% being dead) and 18% severe (over 30% being dead). Work based on global circulation models suggests the cold weather events required to control beetle populations will become less frequent (Carroll et al., 2004).

It appears unlikely that conditions will combine to reduce the expansion of this population to unaffected but susceptible pine forests in the near future. Nonetheless, understanding how beetle biology, lodgepole pine biology and economics interact is important for improving our response to the beetle.

Because many existing lodgepole pine stands are mature, the disturbance threat is ecologically significant. Regardless of whether or not an effective management strategy exists to deal with the mountain pine beetle outbreak, the epidemic will result in considerable socioeconomic impacts, especially in regional communities that depend upon the forest for their livelihood.

Along with the unintended impact of fire exclusion, which resulted in dense forests of older lodgepole pine with heavy fuel conditions, there appears to be a trend of global warming. Average temperatures seem to be above the level of natural variability in the climate system (Crowley, 2000). Carroll et al. (2003) suggest this trend contributes to the current outbreak of mountain pine beetle. If this is the case, then the already catastrophic mountain pine beetle problem in British Columbia has the potential to elevate and spread throughout the boreal forest across western Canada. The potential ecologic and economic crisis resulting from mountain pine beetle outbreak in the boreal forest would increase already major forest health challenges.

While many issues associated with mountain pine beetle deserve attention from economists, the purpose of this chapter is to provide a synthesis of the economic aspects of the issue from a forest management viewpoint. Forest economics is an applied field of economics that deals with economic problems associated with forestland. Nautiyal (1988) divides forest economics into two categories of interest: industry and management, which have both positive and normative aspects. Forest industry economics deals with the study of manufacturing logs from standing forests, their conversion into products, and their trade. Forest management economics deals with economic problems associated with the growing of forests and generating products and services from forestland resources. To the forest economist, humans and many human institutions are equally important to the natural relationships in and between forests.

Mactavish (1965) suggested the application of economic tools such as the minimum-cost-plus-loss criterion to fire control in Canada 40 years ago. The idea would have been appropriate for establishing management levels to form a strategy to protect against large scale increases in beetle populations. Of course, the efficiency of application of this criterion to beetle management would depend upon the generation of quality socioeconomic information. Commenting on a mountain pine beetle epidemic in the province that occurred in the early 1980s, Manning (1982) stated, "...what we do not know about the

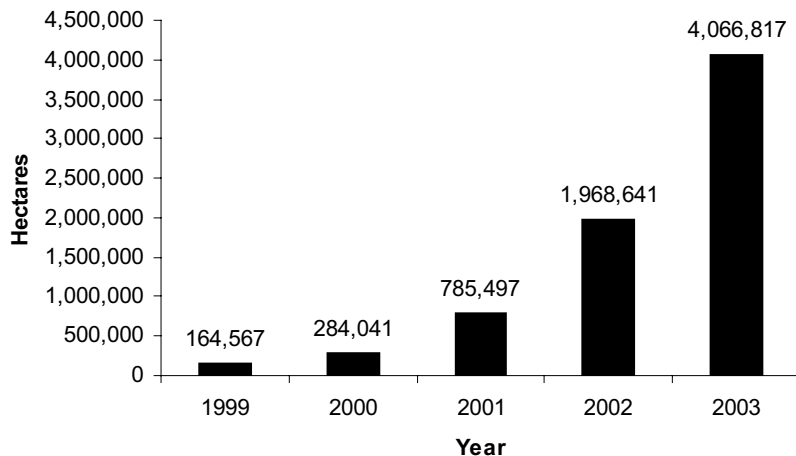


Figure 2. Hectares affected (red attack) by mountain pine beetle in British Columbia (British Columbia Ministry of Forests 2004).

economic impact of the mountain pine beetle far exceeds what we do know, and figures developed from panicky, half-baked analyses have a way of becoming ‘gospel’.”

This chapter begins with a brief presentation of the biological problem of mountain pine beetle management in lodgepole pine. Next, current knowledge concerning mountain pine beetle in British Columbia is discussed. The promise of recent advances in theory relating to economic decision-making in disturbance management is presented after a brief discussion on economics and sustainable forest management. The chapter concludes with a discussion of the future of research in forest economics and economic decision-making in mountain pine beetle management in British Columbia.

### **The biological problem and strategies for managing mountain pine beetle**

Endemic in stands of lodgepole pine and most pine species throughout western North America, the mountain pine beetle is normally limited to highly stressed trees within the pine forest ecosystem (Koch 1996; Raffa and Berryman 1983). However, when certain circumstances combine, such as large areas of mature pine, unregulated fire suppression, and consecutive warm winters, population outbreaks make the beetle a very destructive biological agent in mature pine forests. Logan and Powell (2001) propose that mountain pine beetle plays a regulatory role in the fire ecology of lodgepole pine. First, dead needles of beetle-killed trees provide a highly combustible source of fine fuels. Later, standing dead trees provide vectors for ground fires to reach the forest canopy that would result in stand replacing crown fires that usually favour lodgepole pine regeneration. Goyer et al. (1998) observed that the ecological roles of mountain pine beetle are to open the canopy, thin dense stands of stressed trees, and initiate decomposition. Thus, mountain pine beetle can be viewed as a natural agent of disturbance in the lodgepole pine life cycle.

Abundance and distribution of mountain pine beetle are largely determined by ecological characteristics of lodgepole pine stands and by changes in these characteristics. Lodgepole pine has considerable ecological amplitude that is reflected in the variety of successional conditions under which it thrives. Pfister and Daubenmire (1975) recognize four successional roles of lodgepole pine: minor seral, dominant seral, climax, and persistent. In turn, mountain pine beetle and fire are primary factors affecting the dynamics and successional status of lodgepole pine (Hagle et al. 2000; Mata et al. 2003). Depending on its successional role and its abundance in a stand, mountain pine beetle's impact on stand structure and composition may be predicted (Amman 1977; Logan and Powell 2001). Unfortunately, the larger the area involved, the lower the predictive value of a stand characteristic. Prediction of lodgepole pine mortality, therefore, appears to be most reliable by individual stand basis (Amman and Anhold 1989).

Increased knowledge of mountain pine beetle ecology has led to two very different tactics for reducing lodgepole pine timber losses: direct control and preventive silviculture. Direct control means killing, attracting or repelling the beetles. The effectiveness of direct control is usually only temporary; it may slow the spread and intensity of mountain pine beetle outbreak in susceptible stands until they can be treated silviculturally or salvage logged. Preventive management attempts to keep populations below injurious levels by limiting food source through forest activities intended to maintain or improve tree resistance. Once the beetle population has developed into a large outbreak, salvage logging of just-infested material will not reduce future timber losses (Safranyik, 1982). As with fighting a fire, beetle management should include reducing the potential food supply for the beetles. To be successful in reducing economic and ecological impacts of mountain pine beetle, strategic management approaches must be conceived. These approaches can be tested and built up from the stand level with non-spatial models, such as the British Columbia Ministry of Forests' Forest Service Simulator (British Columbia Ministry of Forests 2004), and with spatial models, such as SELES (Fall, A.; Shore, T.; Safranyik, L.; Riel, B.; Sachs, D. 2002. Application of the MPB/SELES landscape-scale mountain pine beetle model in the Kamloops Forest District, British Columbia Ministry of Forests, unpublished report.).

The Canadian Forest Service published "Management of lodgepole pine to reduce losses from the mountain pine beetle" for public use and application (Safranyik et al. 1974, 1980). These papers discuss a methodology for conserving forest production and are valuable in the effort to manage mountain pine beetle impact on timber production at the stand level. Complements to this work are examinations of costs and benefits, and addressing the question of complex landscape impacts.

Whitehead et al. (2001) discussed landscape susceptibility and suggested the strategy of "...creating a landscape mosaic where age-class, size, stand density, and species distributions do not favour the development of large scale outbreaks." Such a strategy requires money and time. Mitchell (1994) looked at costs associated with commercial thinning to reduce susceptibility to attack by mountain pine beetle, but did not compare costs with the benefits of holding the stand until regeneration harvest.

Cole and Koch (1995) suggest solutions to management of individual lodgepole pine stands so that probability of reaching planned rotation age remains high, despite serious risk from mountain pine beetle and wildfire. To do this, they looked at product yield per unit area of managed lodgepole pine by site class in Montana. Product yield and other values vary throughout British Columbia, but the technique has merit in determining the benefits of a stand-level protection program.

The Canadian Forest Service also maintains a web site that lists some 110 publications on mountain pine beetle. The references offer insight into the mountain pine beetle biology and problem. While some of the literature on the British Columbia mountain pine beetle situation deals with the impact of the bark beetle on production, little of it deals with prices, injury appraisal or economic approaches to evaluating forest-protection alternatives.

### **The mountain pine beetle in British Columbia**

The British Columbia forest situation provides a unique setting in which forest policies are developed. In the province, about 95% of the forestland base, or a total forest area of about 98.4 million ha, is owned by the provincial government. About 53 million ha are considered commercially productive, although only 25 million ha are classified as commercial forest that is designated as the timber harvesting land base (THLB). Mountain pine beetle is attacking pine in all categories of ownership and forest class in the interior of British Columbia. Any strategy for managing the mountain pine beetle must consider that lodgepole pine is found in parks, reserves and other unmanaged areas as well as on the THLB. In the British Columbia context, institutions such as timber tenures and institutional arrangements related to tenures are as important in a socioeconomic analysis as markets, because public forests are managed for multiple values and cannot be treated as solely commercial enterprises.

Until the 1980s, British Columbia public forest managers used a kind of forester's rotation (the age at which current annual increment is equal to the mean annual increment) to determine allowable annual cut (AAC). Inputs from economic analyses, and those from local people were discouraged or not taken into account. This has changed with the new Timber Supply Review processes, which began in 1992.

Also during the 1980s and 1990s, the British Columbia government made substantial decisions about protected areas and forest practices. These included doubling the area covered by protected areas and establishing land-use planning processes such as the Commission on Resources and Environment (CORE) and Land and Resource Management Planning (LRMP). The province's AAC decision process is driven by land-use and forest practices, not the other way around (Pedersen, 2003). Thus, changing forest practices impact the AAC in the various timber tenures initiated as a response to mountain pine beetle. The long-term timber supply on those tenures also has costs and benefits that can be estimated.

Along with a significant public ownership, another element important to the British Columbia context is that only a small domestic market for forest products exists. The

province's forest sector is a major exporter of products, most going to the United States. At present, despite increasing integration of the North American economy, Canada and the USA are embroiled in a trade controversy over the export of Canadian softwood lumber (Hoberg, 2000). The dispute has been almost continuous for the last 25 years, with the most recent trade investigation producing countervailing and anti-dumping duties averaging about 27.2% levied on exports of British Columbia softwood lumber and a suite of forest products to the USA. The resulting constrained access to the American softwood market has severely limited management options available for controlling the mountain pine beetle epidemic in British Columbia.

One result of the continuing softwood lumber controversy is that the British Columbia Ministry of Forests is attempting to create a functional market for timber from the majority of public timber tenures in British Columbia, since April 1, 2004. Although economic ramifications of many changes in forest policy direction are often poorly understood, this does not have to be the case (Haley, 1996). Economic analyses of issues surrounding the beetle epidemic are no exception. Largely because of studies associated with the Forest Practices Code Act, there is emerging understanding of non-market incentives that are embodied in institutions and institutional arrangements in the British Columbia context (Hoberg 2002; Tollerson, 1998) that could be included in economic analyses.

Until the late 1990s, there seems to have been little understanding about how the biology of mountain pine beetle and lodgepole pine relates to forest economics. The British Columbia Ministry of Forests "Socioeconomic Analysis of Mountain Pine Management in British Columbia" web site concludes:

The annual expenditure of \$4.5 million from the current control program results in a net benefit of \$72 million province-wide in stumpage and lumber value (British Columbia Ministry of Forests, 1998).

The analysis was based on a study conducted for the government by Miller et al. (1993). This report examined mountain pine beetle in the Morice and Merritt timber supply areas, and used a modified susceptibility and risk rating system developed by Shore and Safranyik (1992) to project the expansion of beetle damage with the Ministry's non-spatial timber supply analysis technique, Forest Service Simulator (FSSIM). The Shore–Safranyik (1992) susceptibility rating system was validated in 2000, but the effects of modifications made during analysis are uncertain (Shore et al. 2000).

In an effort to glean socioeconomic impacts of beetle management on communities, Miller et al. (1993) interviewed 30 individuals (9 from the forest industry, 12 from various natural resource government departments), and expanded the study to include the whole province. Again, the Miller report suggested large rewards for a modest control program. Unfortunately, the province's control effort has proven to be not very effective in managing the current outbreak. This outbreak is causing far more forest injury and is far more eruptive than previous attacks. As Manning (1982) pointed out more than 20 years ago, much of the problem is due to a lack of reliable information, which results in unreliable economic analyses.



## Administration and management

The British Columbia government recognized an additional need to determine if there was a business case or financial argument to support investment in a management strategy that targets mountain pine beetle. To do that, the government commissioned two studies: one by R. & S. Rodgers (2001), and another by Sterling Wood Group. (Mountain pine beetle epidemic: An estimation of the financial outcomes alternative levels of intervention, British Columbia Ministry of Forests, unpublished report).

The methodology used in the development of the Rodgers' report built on work done through consultations with a cross-section of primary stakeholders. The results of these consultations were presented at three workshops held in the central interior of the province. The objectives of the report revolved around assessing key business issues and their related constraints and identifying viable options for managing the business implications of a worst-case scenario. The report recognized that North American lumber producers currently have excess production capacity and, therefore, recommends that:

... the British Columbia Ministry of Forests and industry exhaust all efforts to maximize the harvest of green attack timber within the framework of revised cost recognition, tenure and operating area transfers and small business forest enterprise program revenue focused licence opportunities before further AAC uplifts are proposed (R. & S. Rodgers 2001).

The Sterling Wood Group study used inventory and cost estimates supplied by the British Columbia Ministry of Forests or implied by various policy statements, assumptions about rate of spread, and assumptions about volume recovery, to construct a matrix for each policy showing the financial impacts to government. The report deals with uncertainty and sensitivity – two problems seldom discussed in government reports. Sterling Wood Group also recommends a “strong plus” intervention, which would mean harvesting 3 million m<sup>3</sup> per year from recent green attack stands and transferring an additional 3 million m<sup>3</sup> of current production logging into stands infested in previous years. The sensitivity analyses suggest that, in redirecting cut, if the original stumpage is less than double the beetle-wood net stumpage, then the Crown would still benefit by making the transfer. Both these two studies recommend the redirecting of existing cut to deal with the beetle epidemic, with the Sterling recommending further uplifts.

British Columbia's chief forester began to clarify some of the major timber-supply impacts of the current mountain pine beetle outbreak in late 2003 (Pedersen 2003a). Although the chief forester's report presented physical terms rather than economic ones, it is an excellent step in coming to economic terms with the nature of the epidemic associated in 12 management units in the central interior of British Columbia. The report sets the stage and allows costs of an uncontrolled epidemic to now begin to be estimated. The study models the flow of pine under a number of assumptions and uncertainties. It suggests that over 200 million m<sup>3</sup> of beetle-killed pine will not be harvested. Under that scenario, harvest would be increased for 15 years by 6.8 million m<sup>3</sup> per year. Then, after 15 years, the flow of timber

will decline by 4.5 million m<sup>3</sup> per year for 65 years – a 19% reduction from current levels of harvest. It is interesting to note that short-term harvests are being increased by 6.8 million m<sup>3</sup> even though redirection of cut is also occurring.

Because the study looks only at the impact of the bark beetle on timber supply and not at other socioeconomic implications of the outbreak, the simulation is one step in assessing the immensity of the problem. Again, although there may be biological and engineering solutions to the mountain pine beetle issue, more work is required to examine what alternatives may mean in terms of costs and benefits to the human communities impacted, and to the province as a whole.

The British Columbia Ministry of Forests defined its strategies and tactics for managing the mountain pine beetle in the Kamloops Forest Region in a handbook (Kamloops Forest Region, 2003). Although it included little about costs and values associated with mountain pine beetle management, the handbook did illustrate how to develop a mountain pine beetle plan, thereby permitting estimation or determination of costs and benefits of mountain pine beetle management at the landscape level. Thus, there is now a basic foundation for analyzing the economic implications of the mountain pine beetle management in the Kamloops Forest Region.

## **Sustainable forest management and the ecosystem approach**

Globally, the field of forest economics is changing. Shifting from an emphasis on stands, the study of landscapes is now required. The production of trees for fibre is no longer the focus: many non-market forest goods and services are becoming objectives in management and stewardship. The move to sustainable forest management (SFM) or ecosystem management requires inclusion of human institutions that would include local municipal governments, firms and households into forest economic alternatives and recommendations.

A major barrier to information diffusion has been that there exists no specialized discipline of “forest protection economics”. To get information on disturbances such as bark beetles, the literature of agriculture, silviculture, entomology, or general forest economics must be reviewed and, even then – especially in the silviculture and entomology literature – economic approaches are often just sidebars to the real purposes of the study. With adoption of ecosystem or sustainable forest management, a new literature, with very different fundamental principles, is developing. Schowalter et al. (1997) discuss integrating ecological roles of insects, pathogens and mycorrhizae into the management of forests; they even cite Mattson and Addy (1975) in challenging the view of mountain pine beetle as pests, suggesting that, in some cases, these organisms actually increase primary productivity through pruning, nutrient cycling and changing species composition. Still, understanding of the interactions between mountain pine beetle–lodgepole pine biology and socioeconomic systems has been slow in developing.

There have been considerable advances in economic analysis of non-priced goods over the past few decades that could clarify an ecosystem approach to the mountain pine beetle issue. Adamowicz et al. (2003) discusses a number of methods for valuing non-timber resources. They define value in terms of the trade-offs people are willing to make and estimate implicit value.

Like Manning, Adamowicz et al. also cite the lack of meaningful data to be applied to analysis, and highlight the problem of only a small pool of qualified workers that work as important factors in the under-incorporation of environmental values into forest decision-making.

There are several ways to analyze the economics of issues that are associated with mountain pine beetle. Although many of the important economic issues associated with mountain pine beetle revolve around the question of value, the problem of approach in identifying what values are to be measured and how also exists. Clearly, at least in the USA, forestry has diverged into two approaches with very different goals. Federal USA forestry is changing to an ecosystem emphasis by identifying and protecting physical, biological and social forest and forest-related values. Although industrial forest owners still focus on increasing forest productivity for wood fibre through application of various cultural tools (Perry 1998), managers and stewards of both jurisdictions remain concerned with long-term sustainability or sustainable forest management (SFM). This trend has become even more pronounced during past two decades (Kant 2003).

Forest managers have traditionally identified the values attached to forests through economic and political systems. Unfortunately, neither forestry nor forest economics has been able to keep up with the paradigm shift to SFM, largely because traditionalists continue to rely heavily on neoclassical economics when examining societal relationships with forests (Kant 2003; Robson et al. 2000). As Kant (2003) notes, “The new forest management paradigm has transformed forest management from timber management to forest ecosystem management, from sustained yield timber management to SFM, and from forest management by exclusion to management by inclusion of user groups.”

Forest economics is becoming more a way of thinking about defining issues than it is a set of dogmas that are instantly applicable to policy development. As Davidson (2002) observes, “Policies deserve to be appraised on their merits. Some will invite more public intervention, others, less. Neither market nor government solutions are without flaw – or merit.” Much of the economics literature on mountain pine beetle has been developed under the “old” paradigm of forest stands in a neoclassical economic world.

The SFM literature suggests at least three reasons for the economic valuation of natural systems and their services (Pritchard et al, 2000). The first has to do with linking natural systems to human welfare; there is a real and close relationship between natural systems and economic well-being of humans (Costanza et al. 1997). Because this relationship is important, natural system values need to be represented in decision-making processes.

Another reason for valuation is to describe the relative importance of various ecosystem types. Lodgepole pine comprises about 25% of standing inventory in the province and is significant in both its contributions to the economic development and maintenance of the forest sector and to provision environmental services of the natural landscape. If mountain pine beetle management is to have long-term impacts on quantity and quality of forest products harvests, this type of valuation is critical in developing and examining management alternatives.

The final reason, which is also the more traditional approach to valuation, is that economic valuation can justify or critique a particular decision or policy direction. Although this third methodology is less useful in ecosystem or SFM approaches to forestland management, it is a necessary first step in developing forest policy, and is critical in establishing institutional arrangements in forest protection (Kimmins, 2002). As such, this method of valuation can be described and justified in terms of gains and losses from a management strategy, as expressed in financial terms. It can be used to help to determine if protection efforts are adequate to the values at risk or, perhaps, suggest alternative courses to current forest-protection direction.

### **Traditional forest economics and mountain pine beetle**

The literature of forest economics on protection and catastrophic disaster is considerable. Forest economics literature deals with the forest management problem caused by mountain pine beetle in lodgepole pine from a number of perspectives. Standard methods are concerned with maximizing value of harvesting a single forest site under the risk of bark beetle. Another viewpoint extends this value-maximizing approach to incorporate multiple uses of, and benefits from, a larger forest system. In this approach, management policy suggests systems that reduce risk in the form of impact reduction rather than product increase. Thus, management costs can be balanced against the reduction of impact – a least-cost-plus-loss economic approach as discussed earlier, which is usually combined with marginal analysis (Herrick 1981; Mactavish 1965).

Both these lines of analysis have roots in forest-rotation models developed around Faustmann's (1849) optimal rotation formula for a single stand and one criterion. Although Calish et al. (1978) demonstrated that the Faustmann approach could be modified to consider joint values in order to determine economic rotations, there are fundamental weaknesses in this traditional damage appraisal model. First, it does not consider the depressing effect that large amounts of salvage timber from catastrophic events may have on the equilibrium market price of wood products in the marketplace; thus, it fails to estimate benefits to consumers and costs to those holding undamaged timber (Holmes 1991). Secondly, it almost totally neglects non-market ecosystem or sustainable forest management values.

Economic damage that results from catastrophe occurs in two ways: through production losses in timber and through costs associated with increasing risks of carrying an economically mature stand to the forester's rotation. When damages are widespread, they can impact timber prices both with and without salvage efforts. Because most of the forests in the province are publicly owned, welfare effects of price variation due to a widespread catastrophe can be significant

(Holmes, 1991). Government's overwhelming participation in public forest management and protection means its policies influence ecosystems on private lands, as well as timber supply and prices from public lands. Thus, examination of welfare effects of forest-protection policies – even if these policies are to do nothing or are unsuccessful – is also critical.

In economic terms, managing situations like the current mountain pine beetle epidemic in lodgepole pine uses scarce resources. Not only are resources being used by management but the flow of future values associated with timber supply and ecosystem health is changing. The matter of direction in which mountain pine beetle control proceeds is a choice. Rational choice by management suggests some criterion for comparing and evaluating alternatives. For effective and efficient selection among alternatives, size and intensity of the outbreak, subsequent impacts, and cost and effectiveness of control alternatives should be considered together as a system. This type of valuation requires use of a large number of variables, which increases probability of error.

### **Economic decision-making and integrated pest management**

Mountain pine beetle becomes a “pest” when the results of its natural activities begin to counter goals and objectives of owners and managers of the forest ecosystem. The promise of integrated pest management (IPM) as a process that brings together information on the ecology of a pest, the pest's impact on societal values, available management tactics and impacts of management on the pest and related ecosystems has been successfully implemented in agricultural systems (Kogan 1998). IPM attempts to develop criteria from which to derive decisions to manage vegetation such as forests to reduce or maintain pest impacts at acceptable levels. To do this, risk assessment methods are used in IPM, based on principles of insect-population dynamics. Risk assessment involves understanding the causes of the damaging event and formulating a predictive model based on this understanding (Berryman and Stark 1985). Shore and Safranyik (1992) devised and tested (Shore et al. 2000) a susceptibility-and risk-rating system for the mountain pine beetle in lodgepole pine stands in British Columbia. Important from an economic perspective, the Shore-Safranyik risk-rating system also provides a tool to predict landscape-level loss due to mountain pine beetle.

Two economic concepts that are well developed in the economic literature of agriculture entomology could be useful in the lodgepole pine case because they provide information on quantifiable aspects of the pest situation. These ideas are termed economic injury level (EIL), defined as the lowest population density of pests that will cause economic damage, and economic threshold (ET).

Peterson and Higley (2002) define economic damage as the amount of injury that justifies the financial cost of control. Linking pest population to degree of damage explicitly recognizes a relationship between pest biology, host biology and economics. Economic injury level, therefore, is a cost–benefit relationship that suggests a level of injury at which the pest management cost equals the cost from losses in forest yield without pest management. Economic threshold is the density of pests at which control measures should be taken to

prevent the pest population from reaching EIL. Nautiyal (1988) suggests that ET is “the point in the development of an outbreak at which control should be initiated.” ET is critical to the EIL concept. Mumford and Norton (1984) consider ET an ideal operational decision rule in agriculture. Fox et al. (1997) develop a framework for applying the ET concept to forest pest management. Economic threshold is a very difficult number or range of numbers to derive, and varies under different conditions (Pedigo, 1996); however, given the work of Shore and Safranyik (1992) and Fox et al. (1997), forest economists are close to creating a useful decision-making tool.

Stern (1973) describes how the ET concept was used in California ponderosa pine (*Pinus ponderosa* Laws) and Jeffrey pine (*Pinus jeffreyi* Balf.) in developing crown classification systems for ponderosa pine under threat of attack from the western pine beetle (*Dendroctonus brevicornis* Lec.) in eastern California. If successfully established in a tree, activities of western pine beetle, similar to those of mountain pine beetle, results in tree death. The importance of classifications discussed by Stern was that a light cut of beetle-susceptible trees for the purpose of sanitation and salvage became possible. Stern concludes that these preliminary cuttings were intended to proceed or delay rotation cutting, and that undesirable clearcut units were not necessary.

Berryman and Stark (1985) use the concept of threshold to assess the risk of eruptive lodgepole pine stand destruction by mountain pine beetle. They define outbreak in terms of gradient, cyclical or eruptive. Because mountain pine beetle is an eruptive outbreak, they suggest a model for developing risk assessment that integrates stand, site and insect numbers, and use lodgepole pine as an example. They define threshold in this case as the beetle population density required to invade a stand of given resistance.

Neither IPM nor its important economic ideas of ET and EIL have yet been fully integrated into forest management and protection plans in British Columbia, although a promise of blending fire, insects, disease and other disturbance factors into forest ecosystem management began to crystallize in the 1960s. By the 1980s, the co-development of the ecosystem concept in natural resources management and radical improvements in computational technology suggested that the integration of forest protection into management plans and operations seemed near to realization (Gara et al. 1985).

Unfortunately, largely because of data requirements in determining ET, that promise has not yet been realized in British Columbia nor in most of North America’s public forests. Although there may be numerous other reasons for this, in the USA, the new management paradigm – ecosystem management – coupled with lower timber harvests on federal forests, along with growing demand and economic timber values, are all contributing to the delay. Increasing forest product values in the British Columbia situation are further complicated by a high proportion of public forest compared to private forest, and by complex timber-tenure arrangements that appear to retard ability of either public landlord or private licensee to strategically respond to landscape-level disturbances such as mountain pine beetle in lodgepole pine.

**Table 1.** Variables in the SELES Model (Fall, A.; Shore, T.; Safranyik, L.; Riel, B.; Sachs, D. 2002. Application of the MPB/SELES landscape-scale mountain pine beetle model in the Kamloops Forest District, British Columbia Ministry of Forests, unpublished report.). (MPB = mountain pine beetle).

Landscape structure
1. Biogeoclimatic classification by variant
2. Elevation in metres
Forest state
3. Age in years
4. Inventory type group
5. Height and volume
6. Percent pine
7. Stand density
8. Site index (height in 50 years)
9. Analysis unit (sites with similar stand conditions, management history and site index.)
MPB population
10. MPB population (beetles per cell)
11. Time since attack in years
12. MPB Susceptibility
13. MPB Risk
Harvest availability
14. Potential treatment type
15. Salvageable volume
Timber harvesting landbase
16. Percentage of landbase in each cell
Management zone
17. Visual quality objective
18. Integrated resource management zone
19. Biodiversity options
20. Landscape units
21. Productive forest (each cell is classed as productive operable, productive inoperable or non-productive)
Management parameters
22. Annual allowable cut
23. Beetle management unit strategies
24. Minimum harvest age
25. Management constraints
26. Management preferences
Roads
27. Distance to existing road in metres

## Future research: Determining economic thresholds in lodgepole pine

Thompson et al. (1992) demonstrates how computer-based analytical models could be used to investigate economic problems and assist with the design of silviculture programs. Phelps et al. (Phelps, S.E.; Thompson, W.A.; Webb, T.M.; McNamee, P.J.; Tait, D.; Walter, C.J., British Columbia silviculture planning model structure and design. British Columbia Ministry of Forests, unpublished report.) developed a computer simulation model to examine silvicultural investment options for forests at the broad strategic level. The model included a subroutine for studying the economics of bark beetle impacts in terms of prices and delivered wood costs. Brumelle et al. (1991) used the Canadian context to review major issues and analytical techniques in silvicultural investment decision making; they observe, “The socioeconomic system involved in the silvicultural investment problem is even more complex and less understood than the biological system” (Brumelle et al. 1991).

Many discussions and techniques described by Brumelle et al. are important in the application of silviculture to beetle protection in stands. Especially relevant is the chapter on silviculture decision making and discussions about risk and uncertainty, sensitivity, discount rate and decision making in a hierarchy. Discussions and allowances for these parameters are largely absent in the Phelps, S.E.; Thompson N.A.; Webb, T.M.; McNamee, D.J.; Tait, D.; Walters, C.J. 1991. “British Columbia silviculture planning model structure and design.” Unpublished report) model, which is basically a bookkeeping device to predict consequences of specified assumptions at the provincial level.

Although not specifically related to barkbeetle dynamics, Stone (1996) completed an economic analysis of commercial thinning of pine for the British Columbia Ministry of Forests. Despite good arguments for commercial thinning at the stand level, the author suggests that at the forest level, commercial thinning will reduce the amount of final harvests allowed in any year. He points out that this economic reversal of going from stand to forest level is an incongruity associated with using total-cut control as a major forest management tool in the province. Stone’s landscape assessment did not include mountain pine beetle risk to lodgepole pine as a factor in the assessment.

By building on the work of Berryman and Stark (1985), and Shore and Safranyik (1992), and by incorporating some of the concepts of Brumelle et al. (1991) into the model developed by Fall, A.; Shore, T.; Safranyik, L.; Riel, B.; Sachs, D. (Application of the MPB/SELES landscape-scale mountain pine beetle model in the Kamloops Forest District, British Columbia Ministry of Forests unpublished report.) it would seem that the concepts of economic threshold and economic injury level could become important contributors to economic decision making in lodgepole pine forests. For the economist, the fact that the biological relationship between mountain pine beetle and lodgepole pine can be modelled is good news. The bad news is the large number of variables that have to be addressed. The large number of variables creates daunting levels of complexity and uncertainty.

Bell Randall (2000) outlines successional functions of mountain pine beetle in lodgepole pine stands with and without fire history and creates about eight scenarios. She points out



that in stands where lodgepole pine is a minor stand component, mountain pine beetle can have a positive impact by thinning pine out of the stand and driving the system toward climax. Fall, A.; Shore, T.; Safranyik, L.; Riel, B.; and Sachs, D. (Application of the MPB/SELES landscape-scale mountain pine beetle model in the Kamloops Forest District, British Columbia Ministry of Forests unpublished report) lists 27 variables used in the spatially explicit landscape event simulator model of the mountain pine beetle in the Kamloops Forest District (see Table 1). A set of complex and considerable data are required on the physical side, and still more variables to do with costs and benefits would be required to allow analysis.

In order to use the SELES model, the data should be both adequate and available, but for many areas of the province, this is not the case. In developing strategic business recommendations for the province, Rogers (2001:12) commented:

...it is absolutely critical to the strategic management of this and other MPB (mountain pine beetle) epidemics to be able to adequately and consistently measure and quantify the level of beetle infestation across the province. While we heard that it is better to over-estimate the scope of the epidemic than to underestimate it, we do not concur with that premise. We believe that if you cannot measure the parameters of the infestation you cannot properly manage it.

The number of variables and data availability or lack of confidence in the data if it exists is a major stumbling block to economic appraisal of the mountain pine beetle issue. On the other hand, strategic models such as that of Phelps, S.E.; Thompson N.A.; Webb, T.M.; McNamee, D.J.; Tait, D.; Walters, C.J., British Columbia silviculture planning model structure and design. British Columbia Ministry of Forests, unpublished report. are available and can be refined with use of models such as the mountain pine beetle SELES approach to begin to assess socioeconomics of the mountain pine beetle epidemics and assess economic implications of adopting some types of strategies and tactics used for managing lodgepole pine and mountain pine beetle.

## Conclusions

The relationship between mountain pine beetle, lodgepole pine and wildfire has been developing in western North America for thousands of years. The attempt to exclude fire from British Columbia forests during much of the 20<sup>th</sup> century has brought about serious economic implications in landscapes that support significant populations of maturing lodgepole pine. This chapter could be seen as a proposal to use economic theory and its related techniques in the landscape management of the mountain pine beetle in the various ecosystems that support stands of lodgepole pine. However, that would be just half a step. Traditionally, the economic aspect of forest decisions focused upon the expected treatment/response relationship in impacted forest stands along with the direct financial costs of the management strategy. This approach often failed to account for uncertainties associated with the selected treatment strategy and usually failed to examine the total economic significance of a selected strategy.

The literature cited in this chapter suggests that there has only been a limited use of economics in mountain pine beetle management in the province. However, using economic theory in conjunction with recent predictive models of beetle behaviour has the potential to guide decision making during the current outbreak and aid with developing a management strategy for lodgepole pine in the future. Cautious interpretation of the strategy in its application to field conditions is also required, as predictive models can be subject to uncertainty from factors that include errors in model input and an incomplete understanding of beetle dynamics and epidemic behaviour. However, even with these uncertainties, models can help understand the complex interactions and outcomes from alternative management scenarios. When coupled with economic analyses, these studies can inform choices and help define strategies that may reduce the impacts of the current epidemic, while considering economic tradeoffs.

Manning (1982), commenting on the mountain pine beetle outbreak of that time, identified five major components of economic impact. These were: 1) impact on allowable cut and value of output, 2) impact on resource flows, 3) impact on product values, 4) changes in protection costs, and 5) changes in forest management costs. If social values were added to the list, Manning's approach would be one useful way to organize an analysis of the socioeconomics of the mountain pine beetle issue in lodgepole pine.

Areas where further research is required include strategies for utilization and market access given the post-beetle timber profile, the social implications of the epidemic to resource-based communities, and the socioeconomic implications of various management strategies. Some of these research topics are currently under the Government of Canada's Mountain Pine Beetle Initiative. Where salvage harvesting is inappropriate like in parks and remote areas, alternative treatments such as the use of fire, or simply leaving the disturbed areas to natural processes, are being explored from both an economic and ecological perspective. Research into longer-term management of affected areas and strategies to minimize risk from future epidemics is also being conducted.

Mountain pine beetle is an important ecological component of lodgepole pine forests, but it also has tremendous economic implications. While silvicultural investments may have the potential to offset some of the timber supply reductions forecast in the aftermath of severe outbreaks, the costs and benefits of such programs are complex and not always apparent at first glance. A careful examination of the economic and social welfare effects of expenditures and investments is needed to guide public managers, particularly where future gains may be subject to increased risk from agents like mountain pine beetle under climatic change.

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